**Review Article**

**WETLAND AS ECOSYSTEM: A REVIEW WITH SPECIAL REFERENCE TO GUJARAT, INDIA**

**ABSTRACT**

|  |
| --- |
| Wetlands offer indispensable ecosystem services and make a substantial contribution to global food security. Safeguarding wetlands from swift alterations and excessive exploitation is essential to preserve their functions. This review aimed to examine the various types, classifications, and functions of wetlands, as well as to present findings on recent research conducted in Gujarat regarding the study of wetlands. This research comprises two key elements: an examination of the various wetland definitions and their categorization as documented in scientific literature; and a methodical evaluation of past research endeavours within each region of Gujarat. The results of the study indicated that Gujarat encompasses a diverse spectrum of wetland ecosystems, such as mangrove forests, freshwater lakes, and coral reefs, among various other types, rendering it one of the most ecologically diverse regions within the nation; furthermore, there exists an urgent imperative to augment the competencies of the scientific community in order to address intricate and globally pertinent issues related to the conservation and sustainable management of Gujarat's wetland ecosystems. |

*Keywords: Aquatic plants; Biodiversity; Ecosystem services; Gujarat; Wetland ecosystems.*

**1. INTRODUCTION**

Wetlands are described as "lands that transition between terrestrial and aquatic eco-systems, typically with shallow water covering the land or the water table at or near the surface" (Mitsch, 2015). Wetlands are among the planet's most productive ecosystems (Ghermandi et al., 2010), and they offer numerous crucial services to human society (ten Brink, 2013). Wetlands are incredibly diverse in terms of their origins, location, water regime and chemistry, dominating species, and features of the soil and sediment (SAC, 2011). Wetland ecosystems span 917 million hectares to over 1275 million hectares globally (Lehner & Finlayson, 2004 & 1999). Their estimated annual economic value is approximately US$15 trillion (MEA, 2005).

In order to promote national action and international cooperation for the preservation and prudent use of wetlands and their resources, the Ramsar Convention on Wetlands was signed in 1971. It defines wetlands as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres”. In India, the majority of man-made wetlands (ponds, farm ponds, irrigated fields, sacred groves, salt pans, reservoirs, gravel pits, sewage farms, and canals) and natural water bodies (rivers, lakes, coastal lagoons, mangroves, peat land, and coral reefs) together make up the wetland ecosystem, according to the Ramsar Convention definition. “Wetlands may include riparian and coastal zones adjacent to the wetlands, as well as islands or bodies of marine water deeper than six metres at low tide lying within the wetlands," according to the Ramsar Convention.

Wetlands have been referred to as biological supermarkets due to the rich biodiversity and vast food webs they sustain, as well as the kidneys of the landscape due to their roles in the hydrological and chemical cycles. It has long been acknowledged that wetland ecosystems benefit people and society in many ways (Maltby, Dugan, Turner et al. & Davis, 1986, 1990, 1990 & 1993). Millions of people are supported by wetlands thanks to their diverse products (such as fisheries products like food sources for a wide variety of fish, shellfish, and other aquatic species) and services (such as the preservation of habitats for various aquatic and terrestrial communities that are used by humans), which benefit both those who live nearby and those who live farther away. Wetland covers only 6.5% of the planet's surface area but provides approximately 14.7% of its ecosystem service values, with an average annual value of $6,000 per acre worldwide (Costanza et al., 1997).

**1.1 Classification of Wetlands**

The process of classifying different types of wetlands can be quite intricate and complex, as more classifications can be made the more factors that are taken into account. According to a basic classification scheme, wetlands can be divided into four main categories: fen, swamp, bog, and marsh. Based on a summary of the literature by Keddy and Moore (2010 and 2008), the following descriptions have been provided:

**Swamp (Carr)-** “A wetland community dominated by trees with a developed leaf canopy, which have invaded from nearby areas into herbaceous marshes and fens, rooted in hydric soils, but not peat; Examples include tropical mangrove swamps and bottom-land forests in floodplains.

**Marsh-** A wetland community dominated by herbaceous plants, usually emergent through water and rooted in hydric soils, but not peat; Examples include cattail marshes around the Great Lakes and reed beds around the Baltic Sea.

**Bog (Schwingmoor)-** A wetland community dominated by sphagnum moss, sedges, ericaceous shrubs or evergreen trees rooted in deep, sometimes uncompacted peat; Examples include blanket bogs which cover mountain sides in Europe and floating bogs which cover the shores of many lakes in temperate and boreal regions.

**Fen-** A wetland community usually dominated by sedges and grasses rooted in shallow peat, often with considerable water movement through the peat; Examples include the extensive peatlands in northern Canada and Russia, as well as smaller seepage areas throughout the temperate zone.”

Keeping these four basic types of wetlands in mind, more advanced classification systems such as those used by the Ramsar Convention (2012) should be considered for comparison. In this system, there are five main wetland systems, each with their own specific subdivisions. The five systems, based upon observations from Ramsar are: Marine- coastal wetlands including coastal lagoons, rocky shores, and coral reefs; Estuarine- including deltas, tidal marshes, and mangrove swamps; Lacustrine- wetlands associated with lakes; Riverine- wetlands along rivers and streams; and Palustrine- meaning "marshy" - marshes, swamps and bogs.

**1.2 Types of Wetlands**

India's extensive geographical expanse is characterized by a wide range of climatic conditions, an extensive coastline, elevated mountain ranges, various surface and subsurface geological structures, diverse forest types, and varied land cover systems. The formation of wetland ecosystems is a direct consequence of the complex interactions among these natural landscapes. The historical interplay between the wetlands of the Indian subcontinent and its inhabitants spanning numerous centuries has rendered these ecosystems truly distinctive. Within this geographical domain, wetlands have significantly influenced the social and cultural fabric of human civilizations, thereby shaping their collective identities.

The Space Applications Centre in Ahmedabad, part of the Indian Space Research Organisation (ISRO), is currently engaged in the implementation of the "National Wetland Inventory and Assessment-2nd Cycle" initiative. The primary objectives of this undertaking include the development of a geographic database encompassing wetlands across the nation, as well as the preparation of a contemporary status evaluation pertaining to wetland areas spanning from the year 2006 to 2007. This evaluation is based on data obtained from the Resourcesat-2/2A and LISS-III sensors during the period from 2017 to 2018. In accordance with the wetland classification framework adopted for this project, wetlands are delineated into two main categories, namely man-made and natural wetlands designated as level-II, with inland and coastal wetlands falling under the level-I classification. These categories are further subdivided into 20 distinct types of wetlands represented as level-III classes within a hierarchical arrangement (Garg et al., 2007). The subsequent section presents a detailed outline of the National Wetlands Classification System, while a visual representation illustrating the diverse array of wetland types is provided in the accompanying figure.

**Table 1. Classification of India's wetlands system.**

|  |  |  |
| --- | --- | --- |
| Level-Ι | Level-ΙΙ | Level-ΙΙΙ |
| Inland Wetlands | Natural | Lakes |
| Ox-Box Lakes/Cut-off Meanders |
| High altitude Wetlands |
| Riverine Wetlands |
| Waterlogged (Natural) |
| River/Stream |
| Man-made | Reservoirs/Barrages |
| Tanks/Ponds |
| Waterlogged (man-made) |
| Salt Pans (Inland) |
| Aquaculture ponds (Inland) |
| Coastal Wetlands | Natural | Lagoons/Backwaters |
| Creek |
| Sand/Beach |
| Intertidal mud flats |
| Salt marsh |
| mangroves |
| Coral Reefs |
| Man-made | Salt Pans (Coastal) |
| Aquaculture ponds (Coastal) |

The definition and description of different types of some wetlands at Level III are defined as follows;

**1.1.1 Human –** **made wetlands:** These are wetlands designed to serve a specific purpose, such as storing water for irrigation and drinking, producing fish, or providing recreational opportunities. Human-made wetlands include reservoirs, aquaculture ponds, salt pans, dams, barrages, and impoundments.

**1.1.2 Lakes:** Known by another name, lentic systems, lakes and ponds are a varied group of inland freshwater habitats found all over the world that serve as vital habitats and resources for both aquatic and terrestrial organisms.

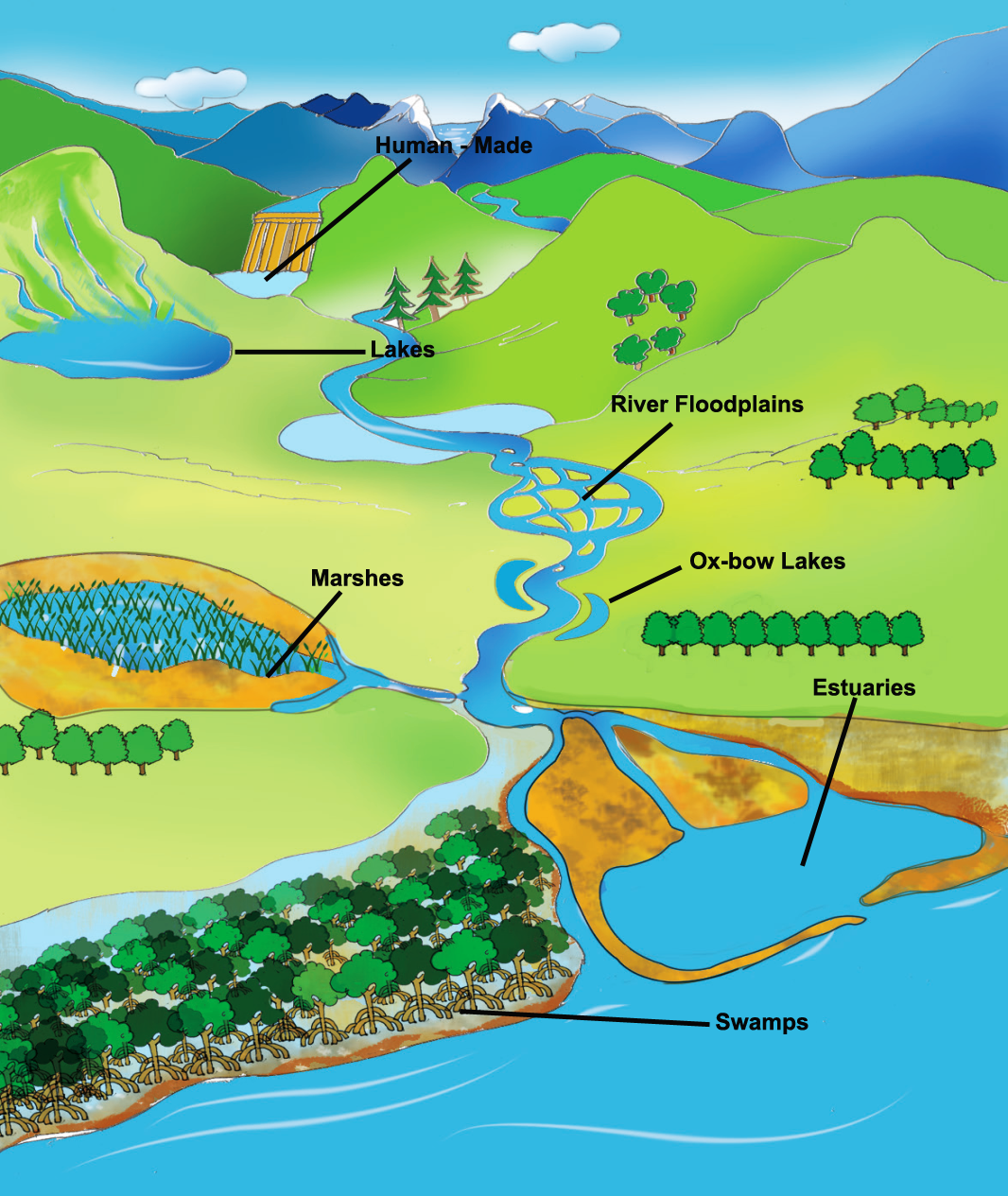
**1.1.3 River Floodplains:** These are the areas next to rivers or streams that occasionally experience water overflowing their channels.

**1.1.4 Ox-bow Lakes:** When a river changes its course or its meander is severed owing to silt deposition, a crescent-shaped body of water is isolated and becomes an oxbow. Oxbows are abundant in the Ganga and Brahmaputra river basins.

**1.1.5 Marshes:** They are primarily supported by herbaceous plants and receive their water from sources other than direct rainfall, such as tidal flow, groundwater, and surface runoff.

**1.1.6 Estuaries:** A semi-enclosed coastal area of brackish water, an estuary receives water from one or more rivers or streams and has an open connection to the ocean. A transitional area between riverine and maritime habitats is created by estuaries.

**1.1.7 Swamps:** Swamps are wetlands where trees predominate. These have inadequate drainage, enough water supply to keep the ground wet, and the right amount of minerals to encourage organism decay and discourage the build up of organic materials. Mangroves are coastal wetlands that abut the nation's largest deltas.



**Fig.1. the different types of wetlands** (Source: <https://indianwetlands.in/wetlands-overview/wetland-types/>)

**1.3 Function Of Wetlands**

Wetlands serve various functions such as improving water quality, retaining floodwater, supporting biodiversity, enhancing visual appeal, and promoting ecological productivity. The value of a wetland is determined by assessing the importance or worth of its social functions.

**1.3.1 Water storage:** Wetlands function as natural reservoirs or sponges that gradually release water over time. They not only reduce flood levels and facilitate the recharge of groundwater but also slow down the speed and erosive power of water, thus aiding in maintaining a consistent flow in surface water systems during dry periods. Although an individual small wetland might not retain a large volume of water, a network of many small wetlands can collectively store a significant amount of water. The economic value of these advantages is appreciated due to wetlands' ability to mitigate flood risks, thereby decreasing the chances of costly property damage and loss of lives.

**1.3.2 Water filtration:** Water flows around plants after being slowed by a wetland, which causes the suspended sediment to fall out and settle on the wetland floor. Plant roots and soil microbes frequently absorb nutrients that are dissolved in water and come from fertilizer applications, manure, leaking septic tanks, and municipal sewage. Additional contaminants adhere to soil particles. By the time the water exits a wetland, this filtration process has frequently eliminated a large portion of its nutrient and pollutant load. Because certain wetlands are so effective at this filtration role, environmental managers create man-made wetlands that are comparable to natural wetlands in order to treat wastewater and stormwater.

**1.3.4 Biological productivity:** Comparable in productivity and species diversity to tropical rain forests and coral reefs, wetlands are among the world's most biologically productive natural ecosystems. Shallow water and an abundance of vegetation offer a variety of habitats for fish and other wildlife. The nutrient-rich environment is ideal for aquatic plant life, and the energy that the plants convert is transferred up the food chain to fish, ducks, and other wildlife as well as to humans. The valuable commercial fish and shellfish industries are supported by this function.

**1.4 ECOSYSTEM SERVICES OF WETLANDS**

The Millennium Ecosystem Assessment (MEA, 2003) defined ecosystem services as "the benefits people obtain from ecosystems." The four categories of ecosystem services (ES) identified by the MEA are provisioning (i.e., ecosystem products like food), regulating, supporting, and cultural services (MEA, 2003).

Although wetlands are crucial for controlling hydrology (Bullock et al., 2003), they have also been referred to as the "kidneys of the landscape" (Mitsch et al., 2007) due to their capacity to enhance water quality through processes like denitrification and sediment retention. However, these procedures may result in the production of greenhouse gases that have an impact on the climate and the quality of the air (Hefting et al., 2006). Additionally, by offering habitats for flora and fauna, they can improve biodiversity conservation (Pilgrim et al. & Hillbricht-Ilkowska, 2010 & 2008). They might contribute to productive systems in some situations, producing biological products as a result. Overall, each ES's unique qualities (such as size and shape), properties, and settings determine its capacity to deliver the ESs indicated in Table 1. Small wetlands, such as those that improve water quality, are frequently able to carry out these tasks more effectively (in terms of area) than large wetlands (Blackwell, 2004).

**Table 2. Description and examples of ecosystem services (ES).**

|  |  |  |
| --- | --- | --- |
| **Service** | **Description** | **Examples** |
| Agricultural production | Agricultural production is defined as the extraction of biological products and services from ecosystems that are innovated and managed by people (following McIntyre et al., 2009). This ES contains all of the provisioning services described in the MEA (2005a, 2005b). With regard to energy we focus on bio-energy production comparing bio-crops, e.g. Miscanthus, Panicum virgatum (switch-grass), with biogas derived from anaerobic digestion of plant material or livestock wastes. | Food (meat, milk), fibre (e.g. cotton), fuel (e.g. wood, biofuel). |
| Water quality | Historically, regulations have focused on chemical determinants, though now the quality of open waters is assessed by using both ecological and chemical methods (Dodkins et al., 2005). The transferral of pollutants from the land to the water typically follows a mobilization-transport-delivery continuum (Haygarth and Sharpley 2000), but it should be noted can occur from both diffuse (from the managed land) and point (from Sewage Treatment Works or farmyard hard-standings) sources. | In grassland-dominated systems water quality is affected by the loss of nutrients primarily, nitrogen (N) and phosphorus (P) in addition to carbon (C), sediment and pathogenic organisms from land-based activities to surface and ground waters. |
| Hydrological regulation | Changes in land management can influence the water cycle by changing: hydrological flow paths and rates, storage capacity in the soil, aquifer interactions as well as plant uptake, storage and release (MEA, 2005a). | Storage of water during rainfall events can help alleviate downstream flooding. |
| Biodiversity conservation | Here we specifically address terrestrial and freshwater aquatic ecosystems and the ecological complexes of which they are part. Most of the research is at the whole organism or the assemblage level, though the diversity of genes, populations and species underlies all grassland ecosystem processes (MEA, 2005a). | Wetlands such as calcareous fens provide habitats for specialized and rare plants and animals. |

**2. WETLAND IN GUJARAT**

Gujarat is India's westernmost state, with the country's longest coastline. The state has a total geographical area of 1,96,024 km2. The state is situated between 20°06' N to 24°42' N latitude and 68°10' E to 74°28' E longitude. Gujarat is regarded as a state rich in wetlands in India. Gujarat is actually the most extensive state in terms of wetland area, accounting for an unparalleled 23 percent of all wetland areas in the nation. According to the Space Applications Center's (SAC-ISRO) the state of Gujarat has 34,749.50 sq.km of total wetland area. It makes up roughly 17.56% of the state's total land area. The state is primarily made up of coastal wetlands, with the three main types being salt marsh (1,442.68 sq.km), creek (1,498.98 sq.km), and intertidal mud flat (22,603.65 sq.km). The two largest inland wetlands in the state are reservoir/barrage (2,489.79 sq.km) and river/stream (2,758.77 sq.km) (SAC, 2011). Four locations in Gujarat have been designated as "Ramsar sites" thus far. which includes the 2012 designation of the Nal Sarovar Bird Sanctuary near Ahmedabad, the Mehsana district's Thol Lake Bird Sanctuary, the Vadodara district's Wadhwana Lake near Dabhoi, and the Jamnagar district's Khijdia Bird Sanctuary as "Ramsar Sites" in 2021.

According to the SAC's (2011) "National Wetland Atlas-Gujarat" Gujarat has 14,183 wetlands total, at least 2.25 ha each. Of these 14,183 wetlands, 1,358 (or 9.57%) are inland natural wetlands spanning 3200 square kilometres, while 10,075 (or 71.035%) are inland man-made wetlands spanning 3400 square kilometres. Regarding coastal wetlands, 2,448 (or 17.26%) are natural wetlands spanning 27,100 square kilometres, while 302 (2.12%) are artificial wetlands encompassing 1,000 square kilometres within the State.The Indian government has designated a number of wetlands in Gujarat as Nationally Important Wetlands. Table 2 provides a description of these wetlands.

**Table 3. List of Nationally important wetlands of Gujarat.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sr.No.** | **Name** | **District** | **Wetland**  **Type** |
| 1 | Khijadia Wildlife Sanctuary | Jamnagar | Natural (Inland)  and Coastal |
| 2 | Nalsarovar Bird Sanctuary | Ahmedabad | Natural (Inland) |
| 3 | Thol Lake Wildlife Sanctuary | Mahesana | Humanmade |
| 4 | Wadhvana Wetland | Vadodara | Humanmade |
| 5 | Banni Grassland | Kutch | Natural (Inland) |
| 6 | Bhaskarpura | Surendranagar | Natural (Inland) |
| 7 | Charakla Salt Pans | Jamnagar | Humanmade |
| 8 | Flamingo City |  | Natural (Inland)  and Coastal |
| 9 | Kaj Lake | Gir Somnath | Humanmade |
| 10 | Marine National Park and Wildlife Sanctuary | Devbhumi Dwarka | Natural (Coastal) |
| 11 | Salt Pans of Bhavnagar | Bhavnagar | Humanmade |
| 12 | Wetlands of Kheda Pairej | Kheda | Natural (Inland) |
| 13 | Wetland of Anand Kanewal | Anand | Natural (Inland)  and Coastal |
| 14 | Wild Ass Wildlife Sanctuary | Kutch | Natural (Inland) |

**2.1 Past Studies In Gujarat**

Numerous ecologists and taxonomists conducted a floristic study on aquatic plants on wetland areas across various regions in gujarat. According to Stanley (2004), Gujarat boasts one of the most varied ranges of wetlands in the nation, encompassing mangroves, freshwater lakes and reservoirs, beaches, mudflats, tidal flats, and coral reefs.

**2.1.1 Central Gujarat**

Deshkar (2016), conducted excellent research on the ecology and diversity of avifauna in wetlands in a semi-arid region of central Gujarat. At Kanewal Reservoir, an internationally significant wetland listed in the Asian Directory of Wetlands, classified as a “Wetland of National Importance” and a proposed community reserve in Gujarat State, a biomonitoring study was conducted (Kumar et al., 2008) in order to determine the water quality index for an evaluation of a tropical aquatic body, the study evaluated a number of different water quality parameters. The interactions between abiotic factors and bird diversity in Gujarat's semi arid zone were studied (Sonal et al., 2010). Another study on Wadhvana wetland suggested a diverse floral community with 82 species and 73 genera from 43 angiospermic families as discussed (Dabgar, 2012).

The surface water quality index of Dakor Pilgrimage Wetland, a tropical sacred wetland in Central Gujarat, was determined (Soni et al., 2013). Another study was conducted on the Shahwadi Wetland (Modi et al., 2013) which is located in Ahmedabad's heavily industrialised Narol area, in total, 24 plant species from 23 genera and 17 families were identified during the research. Another study done (Maitreya, 2015) on the diversity of hydrophytes in a pond close to the Gujarati village of Chiyada, which is situated along the Koth-Bavla Highway and during this study 34 genera and 37 species, representing 23 families, were found in the floral diversity. In Vadodara, Gujarat, a great deal of work was done to analyse the physicochemical parameters over the course of a year in order to determine the quality of two particular ponds, alwa and limda (Patel et al., 2016). During the years 2014–2015, an ethnobotanical research study was carried out to gather, classify, and document a few aquatic and semi-aquatic plants from the chosen locations of Anand Taluka. In all, 42 ethnobotanical plant species from 16 families were identified; these are widely utilised in daily life by the locals and tribal members of the surrounding area in a variety of ways (Patel et al., 2016).

In another study (Suthar et al., 2019) a comparative analysis of some inland wetland’s hydrophyte diversity which compared the hydrophyte species diversity of three inland wetlands in central Gujarat: the Pariej, Kanewal, and Wadhwa wetlands. There are nine species of submerged roots, one species of free-floating roots, five species of floating leafy roots, and five species of emergent hydrophytes among the 19 species of hydrophytes recorded. According (Charan et al., 2019) total 36 species, 32 genera, and 23 families are recorded from Bandali Lake Wetland, Godhra, Panchmahal, Gujarat. According (Patel et al., 2021) the Heranj wetland is home to a total of 28 species of aquatic angiosperms, comprising 8 submerged species, 2 free-floating species, 5 rooted species with floating leaves, and 13 emergent species. In a study conducted on the Pariej Wetland in Kheda, a total of 63 genera and 74 species of flowering plants from 39 families were identified. Of the 74 species, 48 are dicots, which belong to 41 genera and 29 families, and 26 are monocots, which belong to 20 genera and 9 families. According (Gajjar et al., 2021) different species of angiosperms and pteridophytes are recorded from Kanewal Wetland and monocot and dicot families of species are distinguished, and a medicinally significant plant species were recorded.

Another study was conducted on the Nalsarovar area in the Ahmedabad district using Sentinel-2 multispectral data (February 2018), Landsat-7 TM (February 2002), and Landsat-5 TM (February 2009). For improved identification and delineation of aquatic vegetation and water bodies in the Nalsarovar, a variety of spectral indices were created, including the Normalised Difference Turbidity Index (NDTI), the Normalised Difference Water Index (NDWI), and the Normalised Difference Vegetation Index (NDVI) (Chauhan et al., 2021). An additional study conducted (Patel, 2022) upon the findings of the taxonomic research project carried out in Panchmahals District, Gujarat, during 2016 and 2021 in which total of 128 aquatic and wetland angiospermic plant species belonging to 89 genera and 36 families are recorded from 16 lakes of various aquatic habitats from as many villages of Panchmahals during different seasons. An investigation was carried out (Patel et al., 2022) to look at the variety of hydrophytes in Heranj and Kanewal, two significant wetlands in the districts of Kheda and Anand in which 33 species of hydrophytes were identified in all by the study, comprising 9 rooted submerged species, 2 free-floating species, 7 rooted species with floating leaves, and 15 emergent species.

An excellent study was conducted in Ahmedabad, Gujarat State, India, to examine how urbanization is causing a decrease in the total amount of water bodies (Kuchara et al., 2023). In a different study, from December 2020 to March 2021, phytoplankton and zooplankton communities were evaluated in three permanent water bodies located in the Anand and Kheda districts: Petli, Deva, and Heranj and total of 32 phytoplankton was recorded, of which 36% belonged to the class Chlorophyta, 32% to the class Bacillariophyta, 16% to the class Cyanophyta, 10% to the class Charophyte, 3% to the class Dinophyta, and 3% to the class Euglenophyta. In contrast, a total of 27 species of zooplankton have been identified, of which 46% are members of the Maxillopoda phylum, 23% of Monogononta, 19% of Branchiopoda, 8% of Eurotatoria, and 4% of Hexanauplia (Talati et al., 2023)

**2.1.2 Kachchh**

Baseline status of the vegetation in 11 specifically chosen wetlands in the Kachchh district was selected for study (Shah et al., 2010) and a total of 56 plant species, representing 46 genera and 28 families, have been identified from the wetlands. The Gulf of Kachchh was the site of another excellent study conducted between 2011 and 2014, which highlights the diversity of halophytes in the region. In 13 of the Gulf of Kachchh's coastal talukas and islands, 27 halophytes were recorded (Salvi et al., 2017). Another study involved the collection of a soil and water sample from a wetland in the Bhuj Taluka of the Kachchh Region for physico-chemical analysis (Jadeja et al., 2018).

**2.1.3 North Gujarat**

According (Dabgar et al., 2006) a floristic study to investigate the role of the wetland flora in Satlasana Taluka, Gujarat. Another study conducted on wetlands of Vadnagar region in which a total of 49 species of angiosperms from 28 families were identified (Patel et al., 2010). In the Thol Lake Wildlife Sanctuary in North Gujarat, extensive research is being conducted to examine the phytosociology of the various tree species. Thol Lake Wildlife Sanctuary, being a wetland, sustains its vegetation and keeps tree layers green for the majority of the year despite the area falling under a semi-arid zone that is primarily composed of dry deciduous vegetation. In the research region of Thol Lake Wildlife Sanctuary in North Gujarat, an effort has been made to determine the condition of the tree layer (Vyas et al., 2015).

An illustrated and documented floristic research on emergent aquatic and marshland angiosperms was conducted in the Sabarkantha district between 2010 and 2014. In which a total of 54 genera and 74 species were identified, representing 27 families (Patel et al., 2016). Qualitative floristic surveys were conducted in Gujarat, India's Aravalli district in 2015 and 2016. It reveals that the inhabitants of the Aravalli district have long used nearly eighteen species of aquatic and wetland medicinal plants to treat a variety of ailments (Patel, 2018). Field investigations were conducted in the downstream region of the Sipu River, close to the Sipu dam, in the district of Banaskantha, Gujarat, India, from November 2016 to April 2017, with the goal of creating an inventory of the diversity of aquatic and wetland plants. demonstrated the abundance of aquatic and wetland flora in the study area. There were 22 species found in 18 genera and 12 angiosperm families (Bhaskar et al., 2018). Another excellent study was conducted in a selected wetland in the Mehsana district of North Gujarat, where ecological and floristic investigations were conducted (Barot, 2014). In another study about 35 species from 33 genera and 20 families were found in a floristic wetland Angiosperm study conducted in aquatic habitats of Rani Talav, Idar, Sabarkantha district, Gujarat. There were 33 herbs, 1 climber, and 1 shrub among the 35 species. Additionally, 28 upper wetland species, 3 facultative species, and 4 obligatory species were recorded (Charan et al., 2019).

In order to assess the parameters like frequency, density, abundance, related frequency, related density, related abundance, and importance value index (IVI) for each species in Hathidhara Wetland and Its Environs of Palanpur Taluka, Banaskantha District, the survey was conducted from January 2022 to December 2022 (Patel et al., 2023). The phytoplankton and zooplankton communities of the Sabarmati River were assessed over a period of about three years, from January 2017 to December 2019. The primary zooplankton groups identified in freshwater bodies during this study included aquatic weeds such as *Hydrilla, Vallisneria, Chara, Nymphea, Pistia, and Typha,* as well as Protozoa, Cladocera, Copepoda, and Rotifers (Vaghela et al., 2023).

**2.1.4 Saurashtra**

A total of 75 species of aquatic, semi-aquatic, and marshland plants belonging to 61 genera under 37 families were noted in the floristic research carried out in the Porbandar district (Jadeja et al., 2006). The phyto-sociological parameters of the freshwater, inland dry, and marshy habitats of the coastal flora in the 'Bhal' region were studied. In the five sites selected from the "Bhal" region, a total of eight species were recorded (Vyas et al., 2015). A significant effort was made to investigate the α-diversity indicators of halophytes growing in rocky, sandy, and marshy environments along the Saurashtra coast, such as Shannon's index, Simpson reciprocal index, and Pielou's index. The findings revealed that species richness and evenness were at low to moderate levels, while species diversity was relatively low (Gohel et al., 2015).

**2.1.5 South Gujarat**

At the Purna Estuary in Gujarat's Navsari district, the mangroves have been expertly maintained. Six types of salt marsh, nine species of mangrove associates, and seven species of mangroves were recorded from the region during the two years of intensive fieldwork (Bhatt et al., 2009). In the study, which was carried out in Dahej, Bharuch District, Gujarat State, a total of 41 tree species from 20 families were counted within the study area. During the current survey, a total of 27 shrub species from 18 families were recorded from the study area (Kumar et al., 2015). In the Gulf of Khambhat in Gujarat, another study attempted to record the diversity of mangrove plants and their edaphic characteristics. It was discovered that Avicennia marina was the predominant species at all study sites after ecological parameters and edaphic characteristics were examined for three distinct sites: Navsari, Surat, and Bhavnagar (Devi et al., 2016). Another Research work conducted in valsad district in which a total of 43 macrophyte species, which are organized into 35 genera and 24 different families. Out of the 43 macrophyte species, 40 were recorded as angiosperms, 02 as pteridophytes, and 01 as macroalgae (Patel et al., 2023).

**3. CONCLUSION**

Gujarat exhibits a wide array of wetlands including mangroves, freshwater lakes, beaches, and coral reefs, among others, making it one of the most diverse in the country. The process of urbanization that typically accompanies industrial growth has, however, led to environmental deterioration inland, placing significant pressure on the biodiversity of coastal ecosystems. Wetland ecosystems, characterized by their unique biological diversity, are recognized for their intrinsic value as well as their economic importance. Consequently, there is a critical need to enhance the capacity of the scientific community to tackle complex and globally significant challenges, such as the conservation and sustainable management of the biodiversity found within Gujarat's wetland ecosystems.

**4. RESEARCH GAPS AND FUTURE DIRECTIONS**

Although research on Gujarat’s wetlands has expanded in recent years, crucial knowledge gaps remain that limit the formulation of robust conservation strategies. Notably, there is an absence of long-term ecological monitoring frameworks, along with a lack of integration of traditional knowledge from local communities. Studies disproportionately focus on larger and well-known wetlands, overlooking smaller or urban systems. In terms of biodiversity, research remains concentrated on flora and avian species, with minimal attention given to other faunal groups. Furthermore, advanced spatial tools like remote sensing and GIS are underutilized, and there is limited assessment of wetland governance and policy effectiveness.

Hydrological connectivity in Gujarat's wetlands remains underexplored, especially in relation to human-induced pressures like urbanization and agriculture. Future studies should focus on integrated monitoring approaches combining field data, remote sensing, and hydrological models. There is also a critical need for climate risk assessments to guide adaptive management. Incorporating traditional ecological knowledge through participatory methods can improve conservation outcomes, particularly in under-researched regions. A multidisciplinary approach involving ecological, hydrological, social, and policy perspectives is essential. Additionally, developing localized wetland health indicators and quantifying ecosystem services will enhance conservation planning, while regular policy evaluations can help improve the effectiveness of current initiatives.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that no generative AI technologies ChatGPT, COPILOT and text-to-image generators have been used during preparation of this manuscript.

**COMPETING INTERESTS**

The authors declare that they have no competing interests.

**REFERENCES**

Barot, C.J. (2014). Floristic and Ecological study of selected wetlands in mehsana district North Gujarat (Ph.D. thesis). H.N.G.U. Patan: India.

Bhasker, P., Baldev, P., Nikunj, P., Bhavesh, M., Ankit, P. & Vinod, P. (2018). Observation on aquatic and wetland plant diversity in Sipu river bed near Sipu dam, Banaskantha district, Gujarat. *Life Sciences Leaflets*, 100, 53-71.

Bhatt, S., Shah, D.G. & Desai, N. (2009). The mangrove diversity of Purna Estuary, South Gujarat, India. *Tropical ecology*, 50(2), 287-293.

Blackwell, M.S.A., Hogan, D.V., Pinay, G. & Maltby, E. (2009). The role of buffer zones for agricultural runoff. The wetlands handbook. First edition. Chichester, 417–439.

Bullock, A. & Acreman, M. (2003). The role of wetlands in the hydrological cycle. Hydrology and Earth Systems Sciences, 7:358–389.

Charan, R.R. & Solanki, K.J. (2019). Plant Diversity Of Bandhali Lake wetland (Dumelav), Godhra, Panchmahal, Gujarat. *International Journal of Research and Analytical Reviews*, 6(2), 947-952.

Charan, R.R., Oza, K., Maitreya, B.B. & Solanki, H.A. (2019). Angiosperms Diversity of Rani Talav Wetland (Pavapuri), Idar, Sabarkantha, Gujarat. *International Journal of* *Interdisciplinary Research and Innovations*, 7(2), 153-157.

Chauhan, K., Patel, J., Shukla, S.H. & Kalubarme, M.H. (2021). Monitoring Water Spread and Aquatic Vegetation using Spectral Indices in Nalsarovar, Gujarat State-India. *International* *Journal of Environment and Geoinformatics*, 8(1), 49-56.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. & Raskin, R.G. (1997). The value of the world's ecosystem services and natural capital. *nature*, 387(6630), 253-260.

Dabgar, P.J. (2006). A contribution to the wetland flora of satlasana taluka, North Gujarat. *Advances in BioScience*, 5, 79-82.

Dabgar, P.J. (2012). A contribution to the flora of Wadhvana wetland, Dabhoi Taluka (Gujarat) India. *Bioscience Discovery*, 3(2), 218-221.

Davis, T.J. (1993). Towards the wise use of wetlands: Report of the ramsar convention wise use project.

Deshkar, S.L. (2016). Avifaunal diversity and Ecology of wetlands in the semi-arid zone of Central Gujarat concerning their conservation and categorization (Doctoral dissertation). The Maharaja Sayajirao University of Baroda.

Devi, V. & Pathak, B. (2016). Ecological studies of mangroves species in Gulf of Khambhat, Gujarat. *Tropical Plant Research*, 3(3), 536-542.

Dugan, P.J. (1990). Wetland Conservation: A Review of Current Issues and Required Action. IUCN, Gland, Switzerland.

Finlayson, C.M. & Davidson, N.C. (1999). Global review of wetland resources and priorities for wetland inventory. Preface iv Summary Report.

Gajjar, J. & Solanki, H. (2021). Vegetation Analysis of Kanewal Wetland, Gujarat. International *Journal of Scientific Research in Science and Technology*, 8(3), 259-266.

Garg, J.K. & Patel, J.G. (2007). National Wetland Inventory and Assessment, Technical Guidelines and Procedure Manual, Technical Report. Space Applications Centre, ahmedabad.

Ghermandi, A., Van Den Bergh J.C., Brander, L.M., De Groot H.L. & Nunes, P.A. (2010). Values of natural and human‐made wetlands: A meta‐analysis. *Water Resources Research*, 46(12), 1-12.

Gohel, N.A., Mehta, S.K. & Joshi, A.J. (2015). Diversity of halophytes along Saurashtra coast (Gujarat). *International Journal of Physical and Social Sciences*, 5(2), 1-16.

Hefting, M.M., Bobbink, R. & Janssens, M.P. (2006). Spatial variation in denitrification and N2O emission in relation to nitrate removal efficiency in a n-stressed riparian buffer zone. *Ecosystems*, 9(4), 550–563.

Hillbricht-Ilkowska, A. (2018). The mid-European agricultural landscape: catchment-scale links between hydrology and ecology in mosaic lakeland regions. In: Ecohydrology: processes, models and case studies: an approach to the sustainable management of water resources. *CAB International*, 187–206.

Jadeja, B.A., Odedra, N.K. & Vadhiya, H.A. (2006). Aquatic, semi-aquatic and marshland plants of Porbandar district, Gujarat. *International Journal of Plant Sciences*, 1(2), 205-208.

Jadeja, H.V., Tank, S.P. & Ram. V.R. (2018). Physico-Chemical Analysis of Soil and Water Wetland in Bhuj Taluka of Kachchh Region. *Advances in Bioresearch*, 9(2).

Keddy, P.A. (2010). Wetland ecology: principles and conservation. Cambridge university press.

Kuchara, V., Charan, R., Mankad, A. & Solanki, H. (2023). Status Of Selected Wetlands In Ahmedabad. *International Association of Biologicals and Computational Digest*, 2(2), 34-40.

Kumar, A. & Eledath, M. (2015). Baseline status for Flora and Fauna with aquatic biodiversity in Dahej area, district Bharuch Gujarat. *Octa Journal of Environmental Research*, 3(1), 80-93.

Kumar, J.N., Soni, H. & Kumar, R.N. (2008). Evaluation of biomonitoring approach to study lake contamination by accumulation of trace elements in selected aquatic macrophytes: A case study of kanewal community reserve, Gujarat, India. *Applied Ecology and Environmental Research*, 6(1), 65-76.

Lehner, B., Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands. *Journal of hydrology*, 296(1-4), 1-22.

Maitreya, B.B. (2015). Hydrophytes of Pond Near Chiyada Village, Bavla, Gujarat–India. *International Journal of Allied Practice, Research and Review*, 2(5), 29-34.

Maltby, E. (1986). Waterlogged Wealth: Why waste the world's wet places? (1st ed.). Routledge.

MEA (Millennium Ecosystem Assessment). (2003). Ecosystems and human well being: a framework for assessment. Washington, DC: Island Press.

Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-being: Wetlands and Water Synthesis. World Resources Institute, Washington, DC.

Mitsch, W.J. & Gosselink, J.G. (2007). Wetlands. Fourth edn. Chichester: Wiley and Sons.

Mitsch, W.J., Gosselink, J.G. (2015). Wetlands. John wiley and sons.

Modi, N.R., Mulia, N.R. & Dudani, S.N. (2013). Ecological investigations of Shahwadi Wetland. *International Journal of Pharmacy & Life Science*, 4(12), 3193-3199.

Moore, P.D. (2008). Ecosystem; Wetlands, Revised Edition. Facts on File Inc.

Patel, H.A., Sahoo, S. & Thakor A. (2023). Diversity of Aquatic Macrophyte Species of Pardi Wetland, Valsad District, Gujarat, India: Social-economic and Ethnobotanical importance. *Current World Environment*, 18(3), 1325-1336.

Patel, H.R., Prajapati, A.L. & Dabgar, Y.B. (2010). Macrophytic diversity in certain wetlands of surrounding area of Vadnagar (North Gujarat), India. *Plant Archives*, 10(1), 57-64.

Patel, J., Gajjar, J., Maitreya, B. & Solanki, H.A. (2022). A Comparative Account Of Hydrophytes Diversity In Two Inland Wetlands (Heranj And Kanewal) Of Central Gujarat. *International* *journal of multidisciplinary educational research*, 11(3), 9-15.

Patel, J.D. & Maitrey, B. (2021). Diversity of aquatic Angiosperms and Associated Species of Heranj Wetland, Kheda–Gujarat for Sustainability. *International Journal of Scientific* *Research in Science and Technology*, 8(2), 214-222.

Patel, K.R. & Patel, N.K. (2016). Ethnobotanical Study Of Some Important Aquatic And marshy plants of anand taluka of District Anand, Gujarat, India. *Life Sciences Leaflet*, 76, 42-48.

Patel, M.M. (2018). Some aquatic and wetland medicinal plants in Aravalli district of Gujarat. *Journal of Medicinal Plants Studies*, 6(1), 143-145.

Patel, N.B. & Patel, B. (2016). Floristic account of Aquatic and Wetland Angiosperms of Sabarkatha, District Gujarat. *International Journal of Botany Studies*, 1(4), 29-31.

Patel, P.K. (2022). Floristic account of aquatic and wetland angiosperm plants of Panchmahal district, Gujarat. *Nelumbo*, 64(2), 136-146.

Patel, S., Dabagar, Y.B., Dabagar, S.Y. & Makwana, M.C. (2023). Phytosociological Study of Plant Communities in Hathidhara Wetland and Its Environs of Palanpur Taluka, Banaskantha District (NG). *Life Sciences Leaflets*, 161(2023), 1-11.

Patel, T., Rathod, J., Gavali, D. & Lakhmapurkar, J. (2016). Water Quality Of Two Ponds In Waghodiya Taluka, Vadodara District. *International Journal of Chemical and Physical* *Sciences*, 5(1), 41-47.

Pilgrim, E.S., Macleod, C.J., Blackwell, M.S., Bol, R., Hogan, D.V., Chadwick, D.R., Cardenas, L., Misselbrook, T.H., Haygarth, P.M., Brazier, R.E. & Hobbs, P. (2010). Interactions among agricultural production and other ecosystem services delivered from European grasslands. *Advances in Agronomy*, 109, 117–154.

Rajendrakumar, Talati., Nirmal Kumar R., Ravikant Tuteja, D. & Kumar, N. (2023). PHYTOPLANKTON AND ZOOPLANKTON DIVERSITY IN RURAL WETLANDS OF ANAND AND KHEDA DISTRICTS, GUJARAT INDIA. *The holistic approach to environment*, 13(3), 106-112.

Ramsar Convention on Wetlands and World Tourism Organization. (2012). Destination Wetlands: Supporting Sustainable Tourism. The Secretariat of the Convention on Wetlands and World Tourism Organization, Gland and Madrid.

Salvi, H., Das, L., Brahmbhatt, B., Vaghela, N. & Kamboj, R.D. (2017). Diversity of halophytes in Gulf of Kachchh, Gujarat. *International Journal of Life-Sciences Scientific Reserach*, 3(3), 995-1002.

Shah, J.P., Dabgar, Y.B., Jain, B.K. (2010). A contribution to the flora of selected wetlands in Kachchh district of Gujarat. *Asian Journal of Environmental Science*, 5(2), 126-130.

Sonal, D., Jagruti, R. & Geeta, P. (2010). Avifaunal diversity and water quality analysis of an inland wetland. *Journal of Wetlands Ecology*, 4, 1-32.

Soni, H.B. & Thomas, S. (2013). Preliminary assessment of surface water quality of tropical pilgrimage wetland of Central Gujarat, India. *International Journal of Environment*, 2(1), 202-223.

Space Applications Centre. (2011). National Wetland Atlas. Indian Space Research Organisation, Ahmedabad. Study Group on Environment and Report of the study group on environment including tourism, heritage, pollution & disaster management. New Delhi: National Capital Region Planning Board.

Stanley, O.D. (2004). Wetland ecosystems and coastal habitat diversity in Gujarat, India. *Journal of coastal development*, 7(2), 49-64.

Suthar, A.M., Tatu, K., Gujar, R. &Kamboj, R.D. (2019). A comparative account of diversity of hydrophytes in some inland wetlands (Pariej, Kanewal and Wadhwana) of Central Gujarat. *Journal of Life Science*, 9(2), 39-43.

Ten Brink P., Russi, D., Farmer, A., Badura, T., Coates, D., Förster, J., Kumar, R. & Davidson, N. (2013). The economics of ecosystems and biodiversity for water and wetlands. IEEP, London and Brussels, 78:1-105.

Turner, K. & Jones, T. (1990). Wetlands: Market and Intervention Failures. Earthscan, London, UK.

Vaghela, K.B., Shukla, D.P. & Jain, N. K. (2023). A Study of Phytoplankton and Zooplankton Diversity in the River Sabarmati, Gujarat, India. *Asian Journal of Environment & Ecology*, 22(4), 28–38.

Vyas, D.N. & Patel, A.H. (2015). Tree species diversity and their phytosociological evaluation in ‘Thol Lake Wildlife Sanctuary, North Gujarat. *International Journal of Scientific Research*, 4, 713-716.

Vyas, S. & Joshi, A.J. (2015). Quantitative study of coastal flora of Bhal region in Gujarat. *International Journal of Science and Research*, 4(5), 337-341.